STUDY AND DEVELOPMENT OF HAND WRITTEN NUMERAL CHARACTER RECOGNITION

A Thesis Submitted in Partial Fulfilment
of the Requirements for the Degree of

Bachelor of Technology
in
Electronics and Communication Engineering

By

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&
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Department of Electronics & Communication Engineering
National Institute of Technology, Rourkela
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Department of Electronics & Communication Engineering
National Institute of Technology, Rourkela
2015

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

DECLARATION

We hereby declare that the project work entitled "**Study and Development of Handwritten Numeral Character Recognition**" is a record of our original work done under Prof. Sukadev Meher, National Institute of Technology, Rourkela. Throughout this documentation wherever contributions of others are involved, every endeavour was made to acknowledge this clearly with due reference to literature. This work is being submitted in the partial fulfilment of the requirements for the degree of Bachelor of Technology in Electronics and Instrumentation/Communication Engineering at **National Institute of Technology, Rourkela** for the academic session 2011 – 2015.

The results embodied in the thesis are our own and not copied from other sources, wherever materials from other sources are put, due reference and recognition is given to original publication.

SOURAV PODDAR (111EC0149) SAURABH KUMAR SAHOO (111EI0258)

NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA

CERTIFICATE

This is to certify that the thesis titled "**STUDY AND DEVELOPMENT OF HANDWRITTEN NUMERAL CHARACTERS**", submitted by Mr SAURABH KUMAR SAHOO and Mr SOURAV PODDAR for the partial fulfilment of the requirements for the Degree of Bachelor of Technology in 'ELECTRONICS & COMMUNICATION' engineering at the National Institute of Technology (NIT), Rourkela is an authentic work carried out by them under my supervision.

Date:

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Department of Electronics and Communication Engineering

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We would like to take this opportunity to express our gratitude and sincere thanks to our respected supervisor Prof. Sukadev Meher for the guidance, insight, and support that he has provided throughout the course of this work. The present work would never have been possible without his vital inputs and mentoring.

We would like to thank all our friends, faculty members and staff of the Department of Electronics and Communication Engineering, N.I.T Rourkela for their extreme help throughout our course of study at this institute.

SOURAV PODDAR (111EC0149) SAURABH KUMAR SAHOO (111EI0258)

ABSTRACT

Image processing is basically used to extract useful information from any input image. Recognition has a very important role in image processing. In this exploration work, we have concentrated on the recognition of the handwritten numeral characters. Neural Network is used for recognising the different handwritten numerals. Our method comprises of three stages and they are pre-processing, training and recognition.

Pre-processing stages includes removal of noise, binarization, rescaling and finding the skeleton of an image. Skew correction is also used for segmenting the different characters in an image. In training stage we have used back propagation technique for recognising different numeral characters. Different hidden layers are used while training to have better accuracy. Recognition stage recognises the different characters in an image from the trained neural network. The above proposed system has been performed in Matlab. The system detects the numerals with an exactness in around 90-95%.It works well and has the similar accuracy in even twisted pictures or pictures having different size

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Chapter 1

Introduction

1.1 DEFINITION AND BREIF REVIEW

Pattern recognition is a method in which a physical object or event is assigned to one of different pre-defined classes. It is an active field of research which has enormous scientific and practical interest. As it notes, it includes applications in “feature extraction, radar signal classification and analysis, speech recognition and understanding, fingerprint identification, character (letter or number) recognition, and handwriting analysis (‘notepad’ computers)”. Other applications include point of sale systems, bank checks, tablet computers, personal digital assistants (PDAs), and handwritten characters in printed forms, face recognition, cloud formations and satellite imagery. Character is the basic building block of any language that is used to build different structure of a language. Characters are the alphabets and the structures are the words, strings and sentences etc. Character recognition techniques as a subset of pattern recognition give a specific symbolic identity to an offline printed or written picture of a character. The character recognition is basically known as optical character recognition because it involves the recognition of optically processed characters instead of magnetic ones. The main objective behind character recognition is reading input as a sequence of characters from an already existing set of characters. The advantages of the character recognition process are that it can it can save us time as well as effort while developing a digital copy of the document. There is no need to type manually in the future.

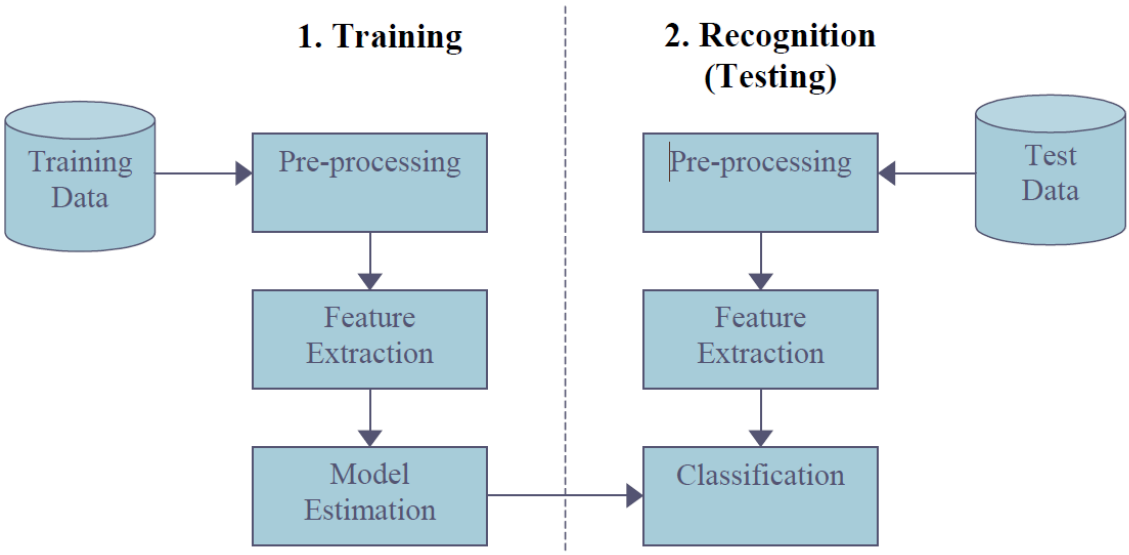
The ANN(Artificial Neural Network) introduced by McCulloch and Pitts in 1943 is an information processing model which is designed by the way the biological nervous system, such as the human brain, processes information. The main component of the ANN model is the innovative structure of the information processing system. It consists of a huge number of processing elements (neurons), interconnected and working in union to solve definite problems. Neural networks are training algorithms that can easily pick up how to crack complex problems from training data that contains of a set of couples of inputs and expected outputs. These can also be trained to execute many specific tasks like estimation and classification. ANNs have been used successfully in many different fields like pattern recognition, speech recognition, and image processing. A lot of scientific efforts have been devoted to pattern recognition areas and much attention has been given to implement recognition systems that can be able to identify an object irrespective of its position, size and orientation. Lately neural networks have been applied to character recognition as well as speech recognition with performance, a lot enhanced than the Conventional method. Different invariant character recognition system based on neural network have been proposed and executed. For example: a neural network based handwritten numeric character recognition without feature extraction were proposed. Here we develop a neural network based size, colour, rotation and style invariant character recognition system which can recognize numbers (0~9) effectively.

Image processing is grouped into two wide regions as, computer graphics and computer vision. In computer graphics, the inputs are typically synthetic from different protests and lighting. Whereas in computer vision, the inputs are generally extracted from video, a PC, cam or a product. It incorporates different systems for securing, processing and analysing pictures. The different undertakings it incorporates are, recognition, motion analysis, scene reconstruction and image restoration, and on account of recognition it incorporates object recognition, identification and detection. In this examination work, another neural system technique is proposed to perceive transcribed numerals. Scanned pictures of manually written numerals are data for recognition.

The aim of our character recognition process is to classify the optical patterns corresponding to numerical characters. This process of recognition includes different stages which involves 1) segmentation, 2) feature extraction and 3) classification. Each of these stages is a large field unto itself, and is defined here in the context of the implementation of character recognition in Matlab.

1.2 THE CLASSIFICATION PROCESS:

A classifier generally involves two stages: 1) training and 2) testing. These stages can be further separated into many sub steps.



1.1 BLOCK DIAGRAM OF OPTICAL CHARACTER RECOGNITION

1. Training

i. *Pre-processing* - This stage transforms and processes data so that it is converted into a suitable and proper form for input to feature extraction.

ii. *Feature extraction* – Decreases the quantity of data by extracting only the important information from the pre-processed data.

iii. *Model Estimation* – This stage estimates a model from the finite set of feature vectors for each set of the training data.

2. Testing

i. *Pre-processing* - This stage transforms and processes data so that it is converted to suitable form for feature extraction.

ii. *Feature extraction* – Decreases the quantity of data by extracting only the important information from the pre-processed data.

iii. *Classification* – This stage compares the feature vectors with different models and finds the nearest match.

CHAPTER 2

IMAGE- PREPROCESSING

2.1 INTRODUCTION

These are the pre-processing steps often performed in OCR:

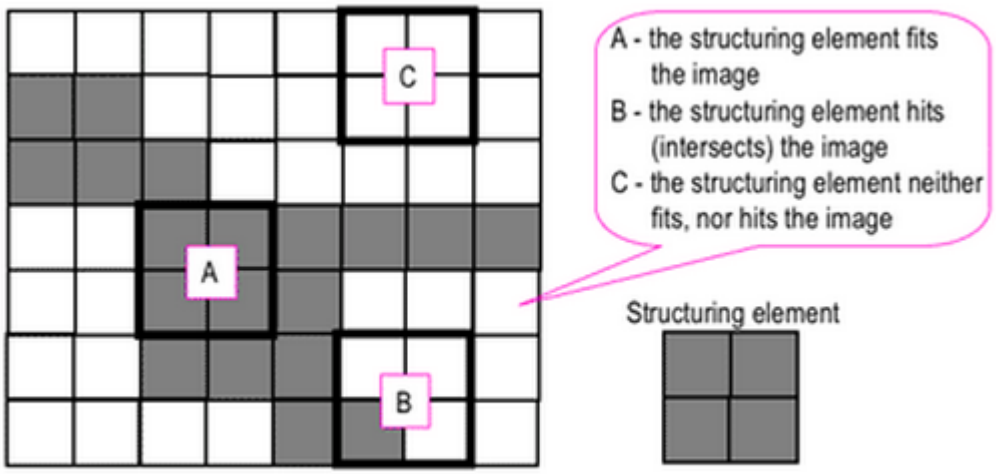
1. Binarization – the image is converted into a grayscale image, through the process of binarization which is done by choosing a threshold value. If the value of the pixel is above the threshold value then it is assigned the maximum value. Otherwise it is assigned the lower value.

2. Morphological Operations – Binary pictures may contain various flaws. Specifically, the double areas created by basic threshold are twisted by clamour and surface. Morphological picture handling seeks after the objectives of uprooting these flaws by representing the structure and structure of the picture. These strategies can be stretched out to greyscale pictures.
Morphological processing of image is a set of non-linear processes identified with the morphology or shape of features in a picture. These operations depend just on the relative requesting of pixel qualities, not on their numerical qualities, and along these lines are particularly suited to the preparing of twofold pictures. Morphological operations can likewise be connected to greyscale pictures such that their light exchange capacities are obscure and subsequently their outright pixel qualities are of no or minor interest.

3. Segmentation – it checks the connectivity of shapes, label, and isolate. This method is used to separate individual lines in an image and then separate individual characters from the separated line.
One of the undoubtedly the most important part of the pre-processing stage is segmentation. It allows us to extract the features from each individual character. But in a complicated and difficult case of handwritten characters, the segmentation process becomes a little difficult as in most of the times the letters are connected to each other.

2.2 MORPHOLOGICAL IMAGE PROCESSING

Morphological methods use a typical layout or matrix called structuring element to test a picture. This structuring element is present at all conceivable areas in the picture and then the corresponding neighbourhood pixels of pixels are compared with the structuring elements. A few operations test whether the component "fits" inside the area, while others test whether it "hits" or crosses the area.



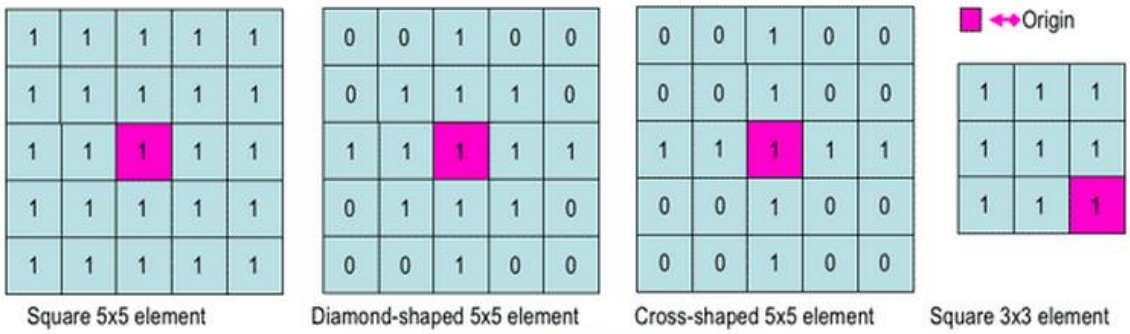
Probing of an image with a structuring element
(white and grey pixels have zero and non-zero values, respectively).

Fig 2.1: Superposition of an image with a structured element

On any binary image, morphological operation creates a new binary image in which if the test is successful at a particular location in the image then the pixel of that location has a non-zero value.

The structuring element is basically a matrix containing values 0 or 1.

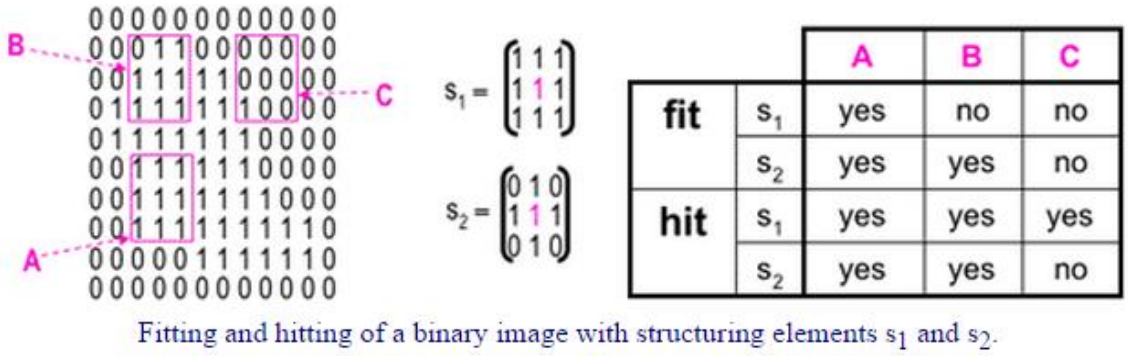
- The dimensions of the matrix determine the structuring element *size*.
- The pattern of zeros and ones determine the structuring element *shape*.
- The structuring element origin is mostly one of its pixels, although the origin can also be outside the structuring element.



Examples of simple structuring elements.

FIG 2.2 EXAMPLES OF STRUCTURING ELEMENTS

A typical practice is having structuring matrix dimensions as odd and the origin characterized as the focal point of the network. Structuring components play in morphological image transforming the same part as convolution portions in linear image filtering. In a binary image, when we place a structured element, each pixel gets associated with its corresponding neighbourhood pixel within the scope of the structured element. If for each pixel set as 1 the corresponding output also comes as 1, then we can claim that the structured element has fit the image. Conversely, if at least for one of the pixels is set to 1 the respective image pixel is also 1 then the structured element has **hit** the image.



		A	B	C
fit	s_1	yes	no	no
	s_2	yes	yes	no
hit	s_1	yes	yes	yes
	s_2	yes	yes	no

Fig 2.3 : Fitting and hitting of a binary image with structured element

All the pixels of the structuring element which are zero are ignored, i.e. It indicate the points where the respective image value is unessential.

2.2.1 FUNDAMENTAL PRINCIPLES OF MORPHOLOGICAL IMAGE PROCESSING:

IMAGE EROSION:

It takes two inputs. First one is the image that is going to be eroded and the other one is the structuring element. For computing the erosion of an input image, we consider all the foreground pixels. Then, we superimpose the structuring element with each of the foreground pixels so that the input pixel position coincides with origin of the structuring element. If every pixels of the structured element corresponds to the foreground pixel in the image, then the input pixel is left as it is.

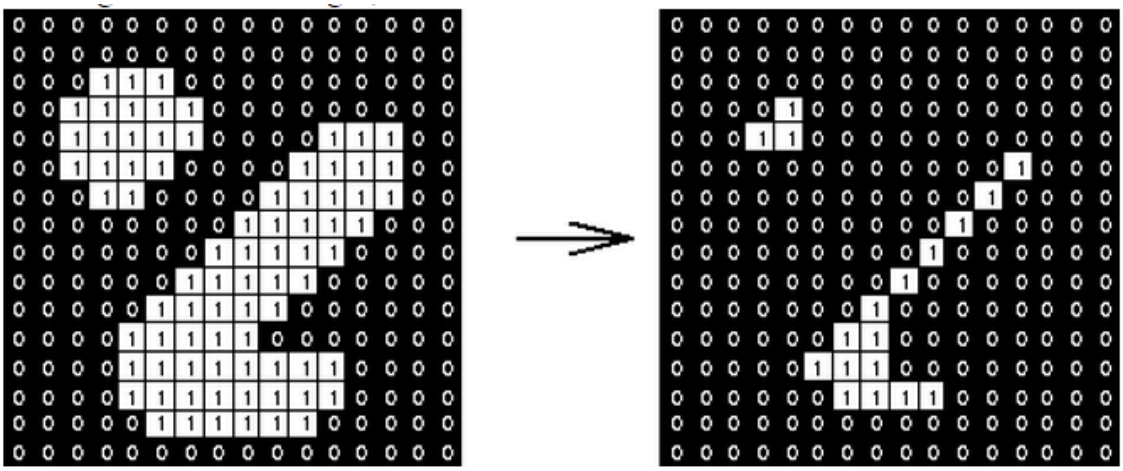


Fig 2.4 : Erosion

IMAGE DILATION

It is the opposite of erosion. It takes 2 pieces of data as input and they are the image that is going to be dilated and the structuring element. For computing the dilation of an input image, we consider all the background pixels. Then, we superimpose the structured element with each of the background pixels so that the input pixel position coincides with origin of the structuring element. If any one of the pixels of the structured element also coincides with the foreground pixel of the image, then the input pixel is set to the foreground value.

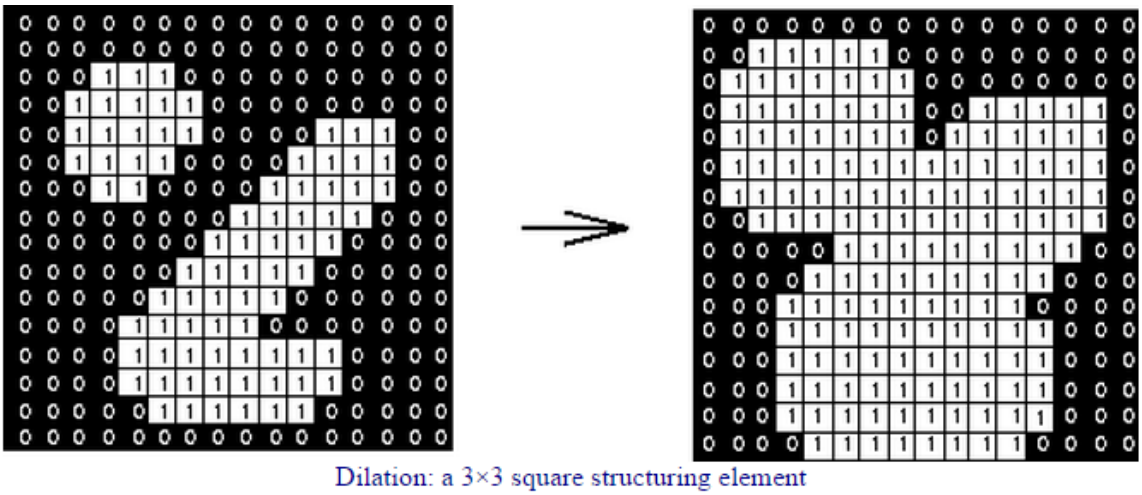


FIG 2.5 DILATION: A 3*3 SQUARE STRUCTURING ELEMENT

HIT AND MISS OPERATION

The hit and miss operation preserves the pixels whose neighbourhood match the shape of SE1 (structuring element) and don't match the shape of SE2(structuring element). SE1 and SE2 are structuring element objects created by strel function or neighbourhood array.

Syntax: BW2 = bwhitmiss(BW1,SE1,SE2)

It is equivalent to

$f \circledast \{s_1, s_2\} = (f \ominus s_1) \cap (f^c \ominus s_2)$

2.3 MEDIAL AXIS TRANSFORM/SKELETONIZATION

Skeletonization is a procedure for lessening foreground regions in a binary picture to a skeletal remainder that to a great extent protects the degree and integration of the first district while discarding the greater part of the first forefront pixels. To perceive how this functions, envision that the frontal areas in the input binary picture are made of some uniform moderate blazing material. Light flames at the same time at all focuses along the limit of this district and watch the flame move into the inside. At points where the flame going from two distinct limits meets itself, the flame will smother itself and the points at which this happens form the alleged `quench line'. This line is the skeleton. Under this definition it is clear that thinning produces a sort of skeleton.

Algorithm used:

- Finding the contour of an image.
- For each pixel, select 5 upper pixels and 5 down pixels.
- Find the angle of all the pixels with respect to the selected pixel along the horizontal line
- Find the median of all the angles found.
- Use geometry to find the coordinates of opposite pixel.
- Find the mid-point between the selected pixel and its opposite pixel.
- Remove all the isolated points.
- The median of the local orientations in the neighbourhood of selected and opposite pixel should at most differ by ±10degrees.

Skeletonization:

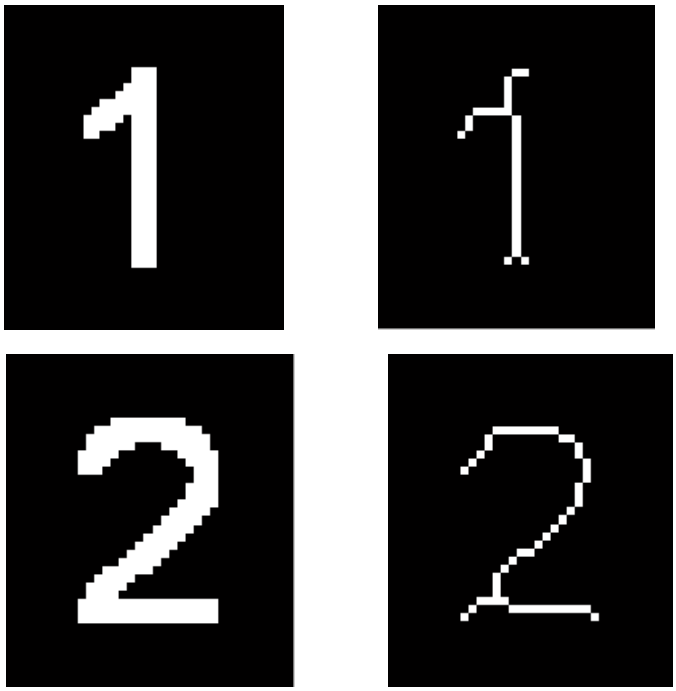


FIG 2.6 SKELETON IMAGES OF SAMPLE IMAGES OF NUMERALS 2 AND 3

2.4 SKEW-CORRECTION OF WORD

The correction of handwritten word skew is a difficult task that must be independent of style and variations in the writing conditions. Least square method is mostly used for the skew correction of handwritten word.

Algorithm used:

- Find the contour of the image.
- Find the minimum points of all the contours.
- Using least square method try to fit the minimum points along a straight line i.e. y=ax+b.
- Find out the slope a and intercept b of the straight line.
- Rotate the image with the slope of the line.

Skew-correction of a word

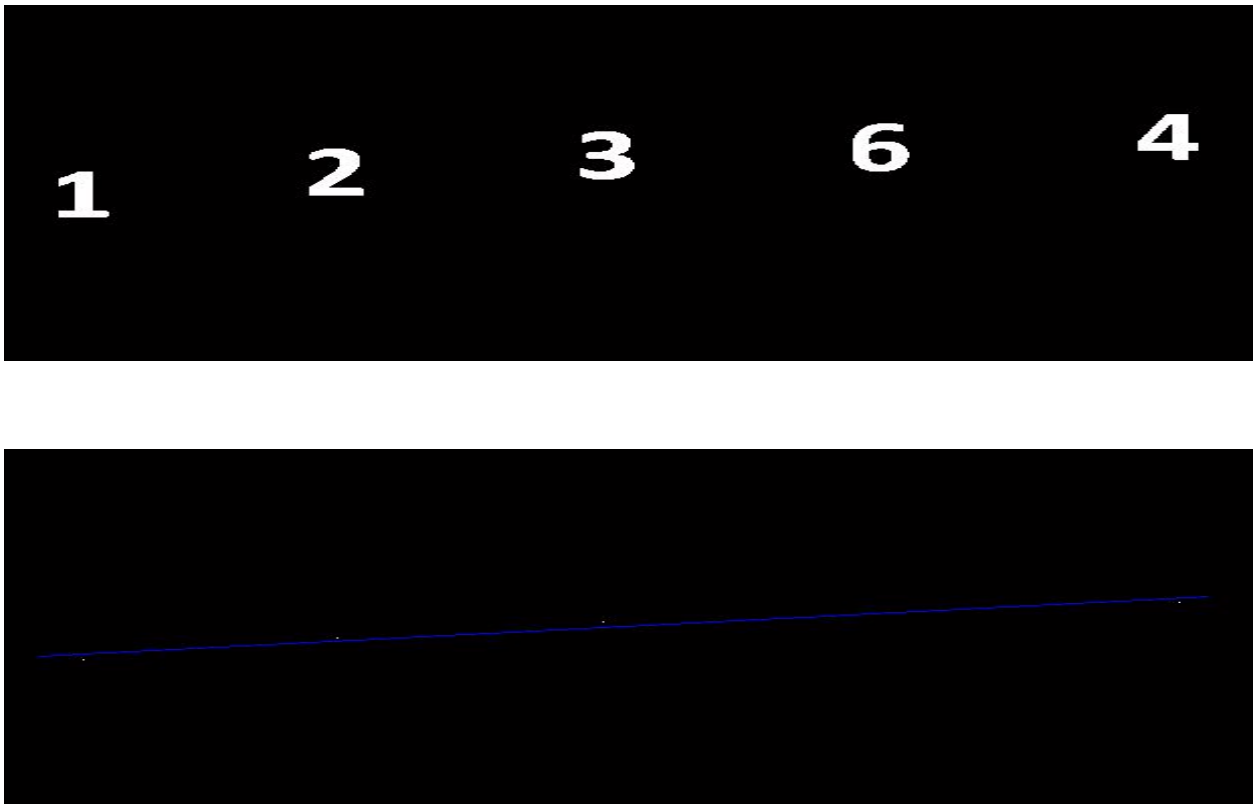


FIG 2.7 SKEW CORRECTION OF A SAMPLE WORD

2.5 NORMALIZATION OF AN IMAGE

In image processing, **normalization** is a process that changes the size of the image. In this process the size of the sample images is adjusted according to a reference image.

Algorithm used:

- Take a reference image and input image.
- Find out the smallest rectangular window that fits the reference image.
- Find out the smallest rectangular window that fits the input image.
- Resize the input image according to the dimensions of the the reference image.

Normalization of an image

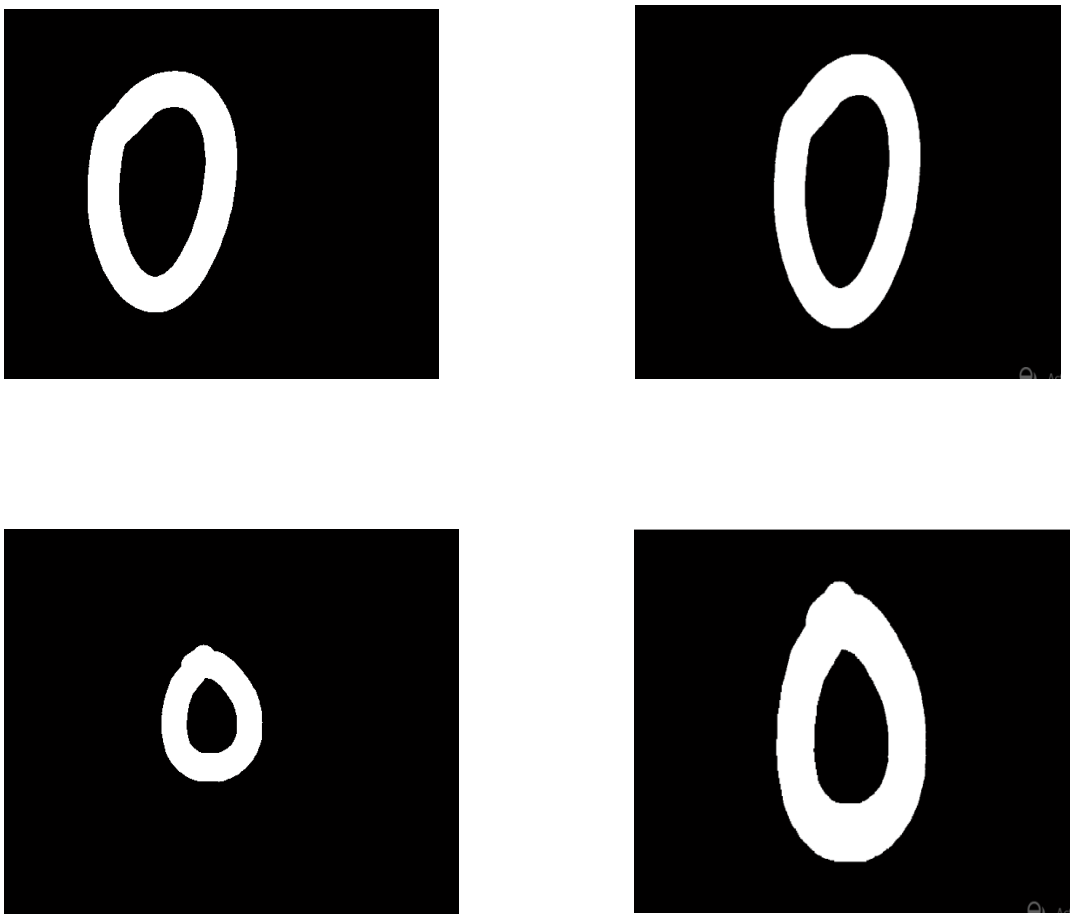


FIG 2.8 NORMALIZATION OF A SAMPLE IMAGE WITH RESPECT TO A REFERENCE IMAGE

2.6 HOUGH TRANSFORM

Hough transform is a method which is used to isolate different features of some particular shape within an image. Since, the desired feature has to be in some parametric form, it is mostly used for the detection of curves such as ellipses, circles, lines, etc.

For E.g:-If there is a set of dicrete image points and we have to fit a set of line segments to it.

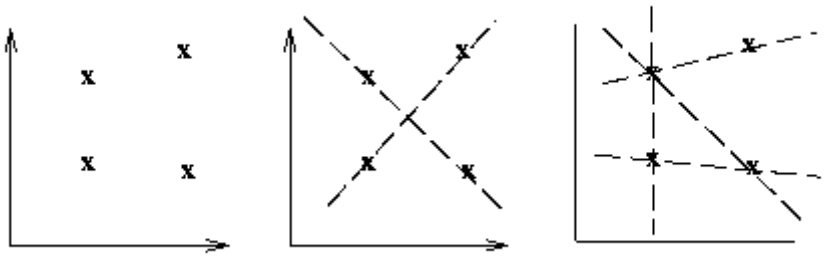


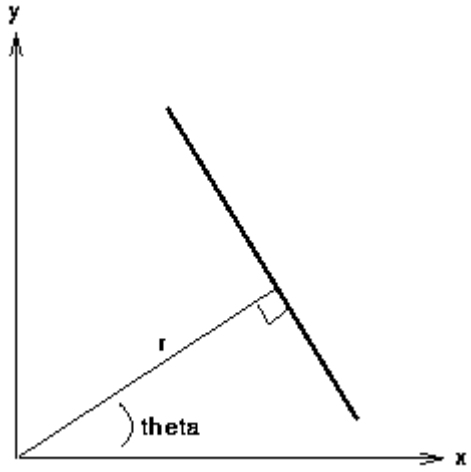
FIG 2.9 FITTING OF A SET OF LINES IN A GIVEN NO. OF POINTS

A line segment can be represented in many forms. However, The most convenient method used for describing the line is parametric form.

$$X \cos\Theta + Y \sin\Theta = r$$

Where r is the length of the normal from origin to the line, theta is the angle made by r with respect to x axis. For every point (x,y) on the line, r is constant.

In hough Space, The points that are collinear in the Cartesian space gives rise to curves that intersect at a common (r,theta) point.



2.7 SOBEL FILTER

It performs a 2D spatial gradient measurement of an image, thus it emphasizes the regions of higher frequency which are the edges. It is used to find the gradient magnitude of every points in a grayscale image.

How It Works: It consists of a pair of 3×3 convolution kernels as shown below. One kernel is simply the rotation of other by 90°.

-1	0	+1
-2	0	+2
-1	0	+1

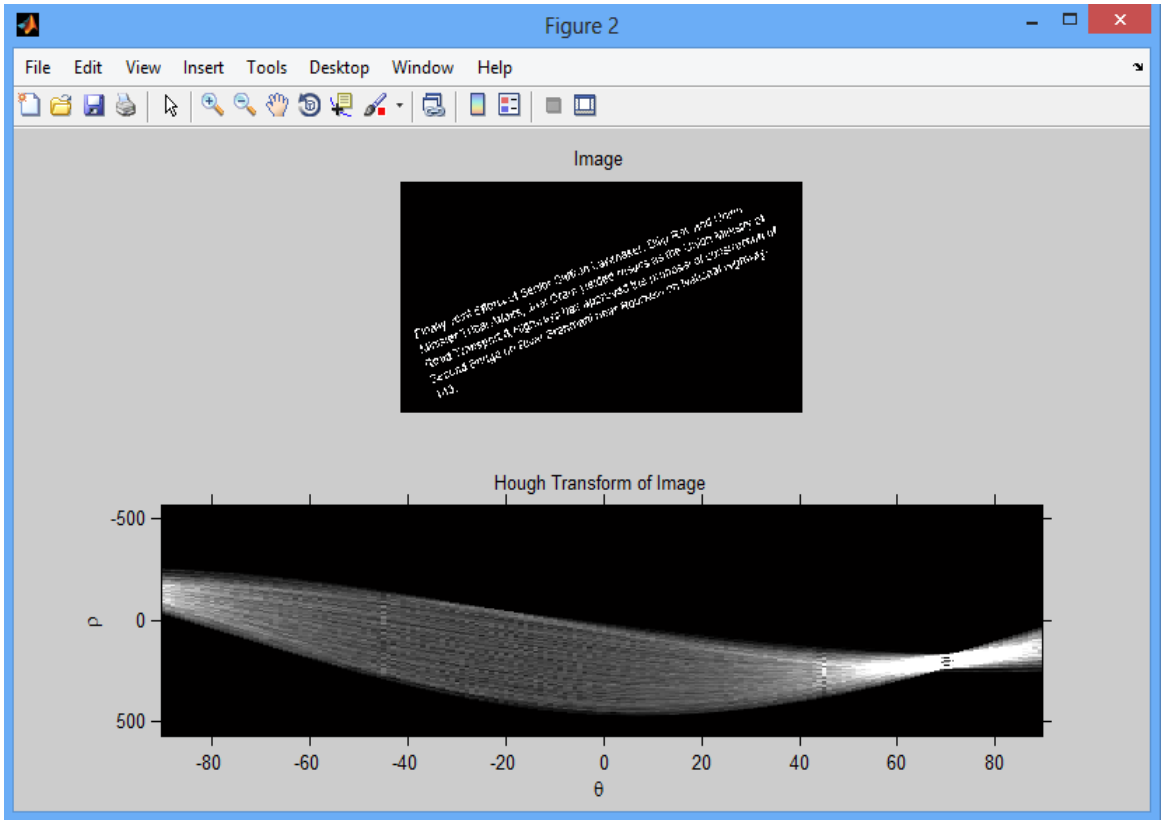
Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

FIG 2.10 EXAMPLES OF SOBEL FILTER OPERATORS

SOBEL FILTER



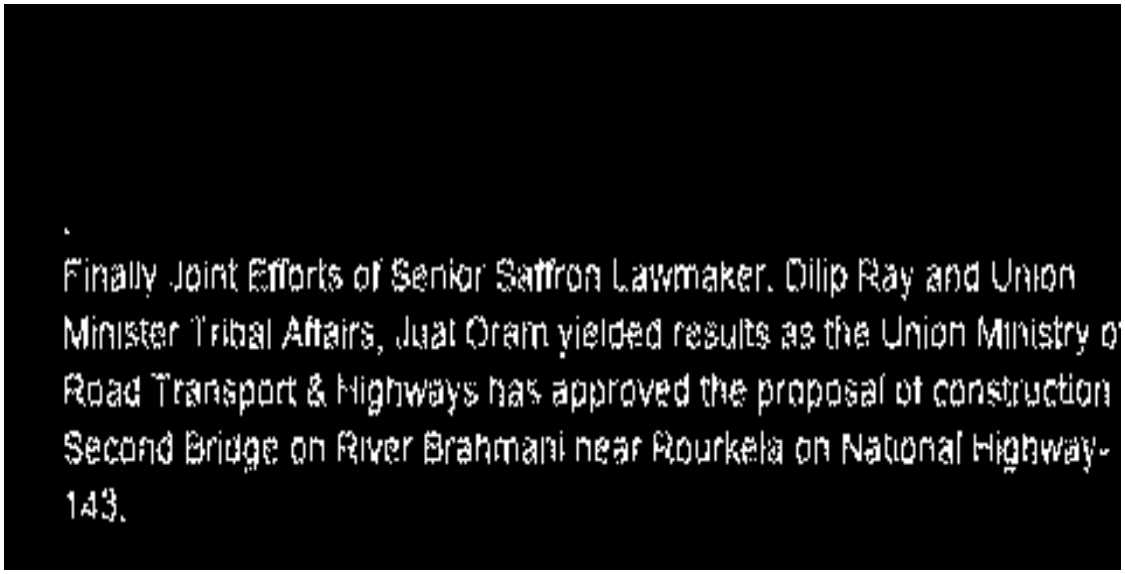


FIG 2.11 IMAGE AFTER SLANT CORRECTION BY USING SOBEL FILTER

2.8 SEGMENTATION

We have taken a binary image. This binary picture comprises of a considerable bunch of items that are differentiated from every other. Pixels that has a place with an object are marked as 1/true while others are marked as 0/false.

Suppose a binary image that looks like

0 0 0 0 0 1 1 1

0 1 0 1 0 0 1 1

0 1 1 1 0 0 0 0

0 0 0 0 0 0 0 1

0 0 0 0 0 0 1 1

0 0 1 1 1 0 1 1

We can see that there are 4 objects in the above image. The definition of an object in the picture are those pixels that are 1, that are associated in a chain by taking a look at nearby neighbourhood.

Our output will be given as an integer map where every object is assigned an unique id. The yield would look something like this

0 0 0 0 0 3 3 3

0 1 0 1 0 0 3 3

0 1 1 1 0 0 0 0

0 0 0 0 0 0 0 4

0 0 0 0 0 0 4 4

0 0 2 2 2 0 4 4

because, Matlab processes things in a column major, that's why the marking has been done on the way we see above. As such, this procedure gives as the enrolment of every pixel. This lets us know where every pixel fits in, if it falls on an object 0 it corresponds to background.

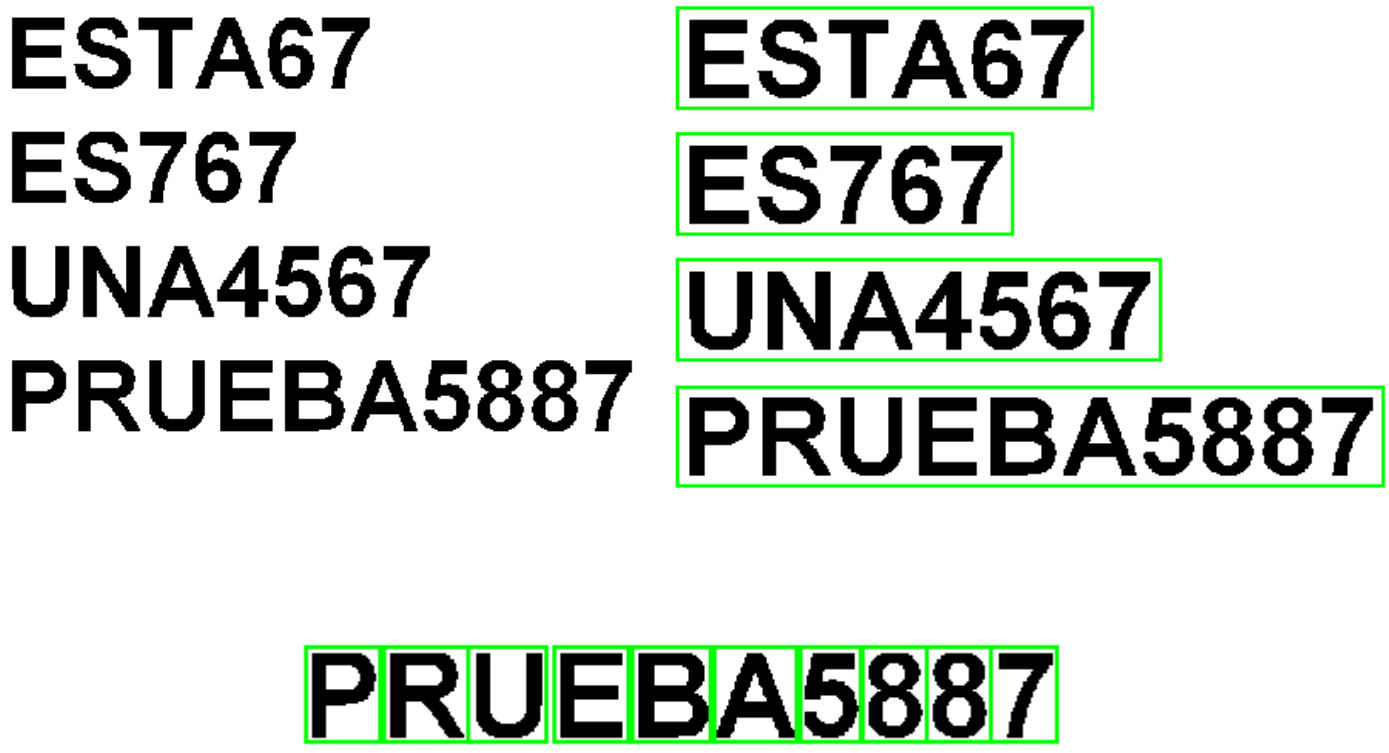


FIG 2.12 SEPARATION OF LINES AND SEPARATION OF CHARACTERS

CHAPTER 3

FEATURE EXTRACTION

3.1 INTRODUCTION

Decreases the amount of data by extracting only the important information from the pre-processed data.

It includes two process:

1. Histogram method

   In this method no. of elements for each direction in the chain code is found out. Then all the elements have been normalised and finally fed into the input layer of the neural network.

2. Elliptical Fourier transform

3.2 CHAIN CODE AND FREEMAN CODE ALGORITHM

1. Input to the OCR

The Input image should be in .png/.bmp/.jpg format. The image should be a binary one. The colour of the text should be black and the background colour should be white .Thus, the image can have only two pixel values, 1, for background (white) and 0, for the foreground (black).

1. Boundary Detection

The function bwboundaries traces the boundaries in a binary image. It can trace the exterior boundaries of objects, as well as boundaries of holes inside these objects.

2. Chain code

Chain codes is a method that is mostly used for tracing and describing a contour. In this technique the boundary of a contour is represented by 4 directions, that are right (0),down (1), left (2), and up (3).If we assume that there are p number of boundary points then, the array C(p)=0,1,2,3,contains the chain code of the boundary. Freeman code is a improved version of the chain code that uses eight directions instead of four.

We can convert the resulting chain code array into a rotation-invariant equivalent, by a method called as the first difference. In this method the number of changes in the direction is expressed in the multiples of 90, between any two consecutive elements of the Freeman

code. Now the array is rotated circularly until we get the smallest first difference at the beginning which is known as the shape number of the contour. Shape number is rotation invariant and it also doesn't depend on the starting point.

If the directions are only 4, then it is called as chain code and if there are 8 directions then it is called freeman code.

a. chain code b. freeman code

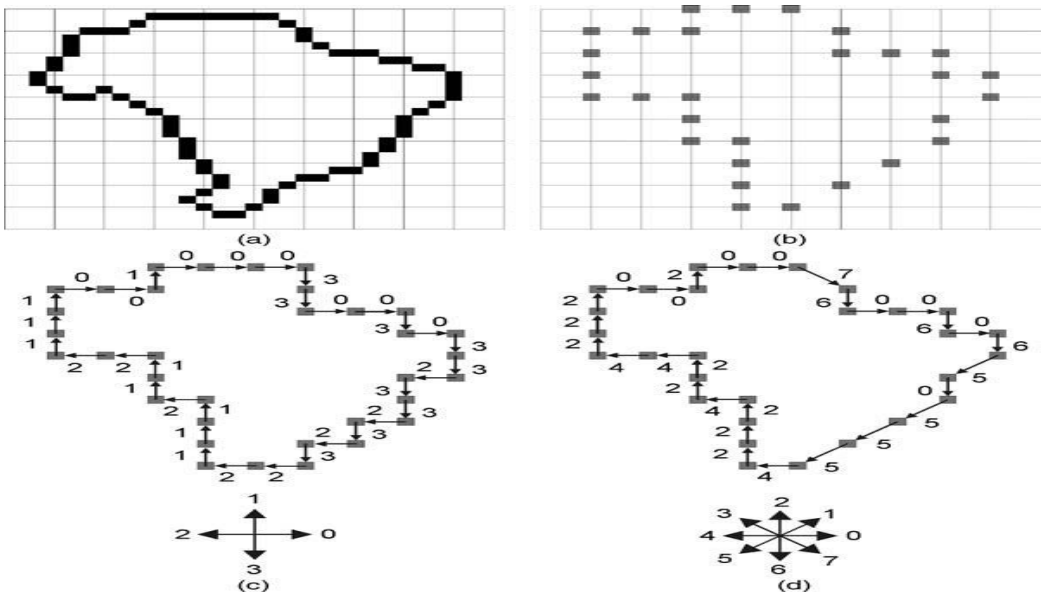


FIG 3.1 CHAIN CODE AND FREEMAN CODE REPRESENTATION

Another example of chain code:

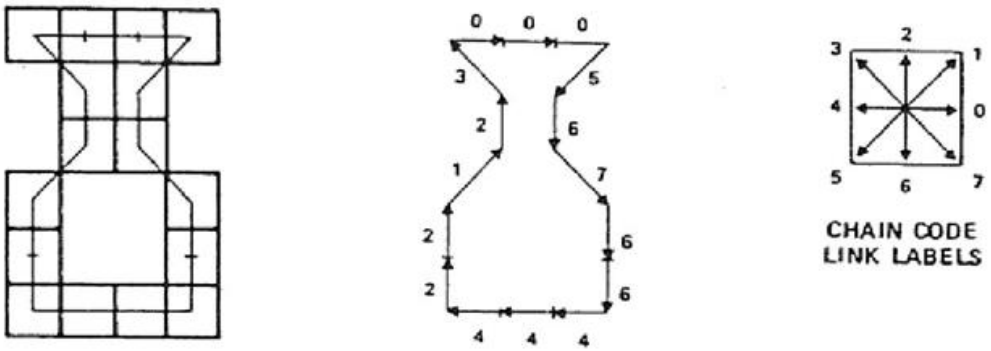
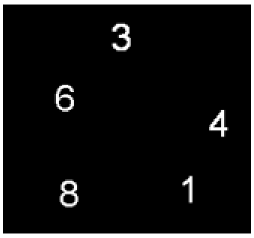


FIG 3.2 EXAMPLE OF FREEMAN CODE

Simulation Results:-

Training Samples



Test Image

Code for 1: [7 7 0 7 7 7 6 0 0 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 4 4 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 5 3 3 4 3 4 6 6 0]

Code for 2:[7 6 7 0 7 0 0 0 0 0 0 0 0 1 0 1 2 1 2 2 2 2 2 2 3 3 3 3 3 3 3 3 4 3 3 3 1 0 0 0 0 0 0 0 0 0 0 2 2 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 6 6 7 6 7 7 0 7 7 7 7 7 7 7 7 7 6 7 5 5 5 4 5 4 4 3 4 3 3 3 4 4 6 6 0]

Code for 4: [7 6 7 7 7 6 7 7 7 6 7 7 7 6 7 0 0 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 0 0 2 2 4 4 3 2 2 2 2 2 4 4 6 6 6 6 6 5 4 4 4 4 4 4 4 4 4 4 6 6 6 0]

FIG 3.3 CHAIN CODE FOR DIFFERENT NUMERALS IN A SAMPLE IMAGE

CHAPTER 4

TRAINING AND RECOGNITION

4.1 INTRODUCTION

Training and recognition utilizes feed forward back propagation algorithm. The new technique proposed in this research work actualizes the recognition with programming coding. It adopts Multilayer feed forward neural system building design. The explanation behind utilizing feed forward neural system is that, they are the most straightforward type of cooperative memory, and they have the ability to gain as a matter of fact, sum up from past samples to new ones furthermore separate key characters or highlights from different inputs that contain immaterial information. The proposed strategy is connected over diverse information pictures. The recognition precision is reliable notwithstanding for deformed pictures.

4.2 ELLIPTICAL FOURIER TRANSFORM

Fourier descriptor has been effectively used for the characterization of closed contours. Here we have utilized a basic approach to acquire the Fourier coefficients of a chain coded form as well as error bound of such a representation. Fourier descriptor are invariant with translation, dilation, rotation of the contour, and also doesn't depend on the starting point of the contour, and also with the starting point on the contour.

Fourier Coefficients of a chain code

Let us assume a closed contour has a chain code V1 having length K

V1 = a1 a2 a3 a4 a5…….

where $\underline{a_i}$ is an integer in the range 0 to 7 having a direction (Ⅲ/4)a_i and all are of length 1 or sqrt(2) and that depends on whether a_i is even or odd. The vector notation of each a_i is represented as

$$\left(1+\frac{(\sqrt{2}-1)}{2}(1-(-1)^{a_i})\right)\angle\frac{\pi}{4}a_i.$$

An example of a chaincode ,

V1=0005676644422123

In this section, The fourier coefficients developed for a chain-coded contour is for a specific starting point on the contour.

If we assume constant speed, then the time needed to traverse a specific link a_i is

$$\Delta t_i = 1+\left(\frac{\sqrt{2}-1}{2}\right)(1-(-1)^{a_i}).$$

Then the total time required to traverse the first p links of the chain are

$$t_p = \sum_{i=1}^{p}\Delta t_i$$

The basic period of the chain code is $T=t_k$. As the link a_i is traversed, changes in the x , y projections of the chain are as follows

$$\Delta x_i = \operatorname{sgn}(6-a_i)\operatorname{sgn}(2-a_i),$$
$$\Delta y_i = \operatorname{sgn}(4-a_i)\operatorname{sgn}(a_i),$$

If the starting point of the chain code is located at the origin, then the x and y projections of the first p links of the chain are respectively

$$x_p = \sum_{i=1}^{p} \Delta x_i,$$

$$y_p = \sum_{i=1}^{p} \Delta y_i.$$

The fourier series representation for the x projection of the chain code is represented as

$$x(t) = A_0 + \sum_{n=1}^{\infty} a_n \cos\frac{2n\pi t}{T} + b_n \sin\frac{2n\pi t}{T},$$

where

$$A_0 = \frac{1}{T}\int_0^T x(t)\,dt,$$

$$a_n = \frac{2}{T}\int_0^T x(t)\cos\frac{2n\pi t}{T}\,dt,$$

$$b_n = \frac{2}{T}\int_0^T x(t)\sin\frac{2n\pi t}{T}\,dt.$$

The Fourier coefficients in this expression corresponding to nth harmonic; a_n and b_n can be found out easily since x (t) is a continuous and piecewise linear for all time. The derivation of coefficients here involves the time derivative d(x (t)), i.e.$\Delta x_p / \Delta t_p$ associated with time intervals $t_{p-1} < t < t_p$ for $1 \le p \le K$. The time derivative of x (t) is periodic with basic period T and can be expanded by the Fourier series

$$\dot{x}(t) = \sum_{n=1}^{\infty} \alpha_n \cos\frac{2n\pi t}{T} + \beta_n \sin\frac{2n\pi t}{T},$$

$$\alpha_n = \frac{2}{T}\int_0^T \dot{x}(t)\cos\frac{2n\pi t}{T}\,dt$$

$$\beta_n = \frac{2}{T}\int_0^T \dot{x}(t)\sin\frac{2n\pi t}{T}\,dt$$

Where

$$\alpha_n = \frac{2}{T}\sum_{p=1}^{K}\frac{\Delta x_p}{\Delta t_p}\int_{t_{p-1}}^{t_p}\cos\frac{2n\pi t}{T}\,dt$$
$$= \frac{2}{T}\sum_{p=1}^{K}\frac{\Delta x_p}{\Delta t_p}\left(\sin\frac{2n\pi t_p}{T} - \sin\frac{2n\pi t_{p-1}}{T}\right)$$

$$\beta_n = \frac{2}{T}\sum_{p=1}^{K}\frac{\Delta x_p}{\Delta t_p}\int_{t_{p-1}}^{t_p}\sin\frac{2n\pi t}{T}\,dt$$
$$= -\frac{2}{T}\sum_{p=1}^{K}\frac{\Delta x_p}{\Delta t_p}\left(\cos\frac{2n\pi t_p}{T} - \cos\frac{2n\pi t_{p-1}}{T}\right)$$

But d(x(t)) of the above fourier series representation is

$$\dot{x}(t) = \sum_{n=1}^{\infty} -\frac{2n\pi}{T}a_n\sin\frac{2n\pi t}{T} + \frac{2n\pi}{T}b_n\cos\frac{2n\pi t}{T}.$$

Equating the coefficients, we get

$$a_n = \frac{T}{2n^2\pi^2}\sum_{p=1}^{K}\frac{\Delta x_p}{\Delta t_p}\left[\cos\frac{2n\pi t_p}{T} - \cos\frac{2n\pi t_{p-1}}{T}\right],$$
$$b_n = \frac{T}{2n^2\pi^2}\sum_{p=1}^{K}\frac{\Delta x_p}{\Delta t_p}\left[\sin\frac{2n\pi t_p}{T} - \sin\frac{2n\pi t_{p-1}}{T}\right].$$

Similarly, The fourier series expansion for the y projection of the chain code is

$$y(t) = C_0 + \sum_{n=1}^{\infty} c_n \cos\frac{2n\pi t}{T} + d_n \sin\frac{2n\pi t}{T}$$

$$c_n = \frac{T}{2n^2\pi^2} \sum_{p=1}^{K} \frac{\Delta y_p}{\Delta t_p} \left[\cos\frac{2n\pi t_p}{T} - \cos\frac{2n\pi t_{p-1}}{T}\right]$$

$$d_n = \frac{T}{2n^2\pi^2} \sum_{p=1}^{K} \frac{\Delta y_p}{\Delta t_p} \left[\sin\frac{2n\pi t_p}{T} - \sin\frac{2n\pi t_{p-1}}{T}\right]$$

The DC components in the fourier series are as follows:

$$A_0 = \frac{1}{T} \sum_{p=1}^{K} \left[\frac{\Delta x_p}{2\,\Delta t_p}(t_p^2 - t_{p-1}^2) + \xi_p(t_p - t_{p-1})\right]$$

$$C_0 = \frac{1}{T} \sum_{p=1}^{K} \frac{\Delta y_p}{2\,\Delta t_p}(t_p^2 - t_{p-1}^2) + \delta_p(t_p - t_{p-1}).$$

$$\xi_p = \sum_{j=1}^{p-1} \Delta x_j - \frac{\Delta x_p}{\Delta t_p} \sum_{j=1}^{p-1} \Delta t_j$$

$$\delta_p = \sum_{j=1}^{p-1} \Delta y_j - \frac{\Delta y_p}{\Delta t_p} \sum_{j=1}^{p-1} \Delta t_j$$

$$\xi_1 = \delta_1 = 0.$$

FOURIER TRANSFORM APPROXIMATION OF SOME NUMBERS:

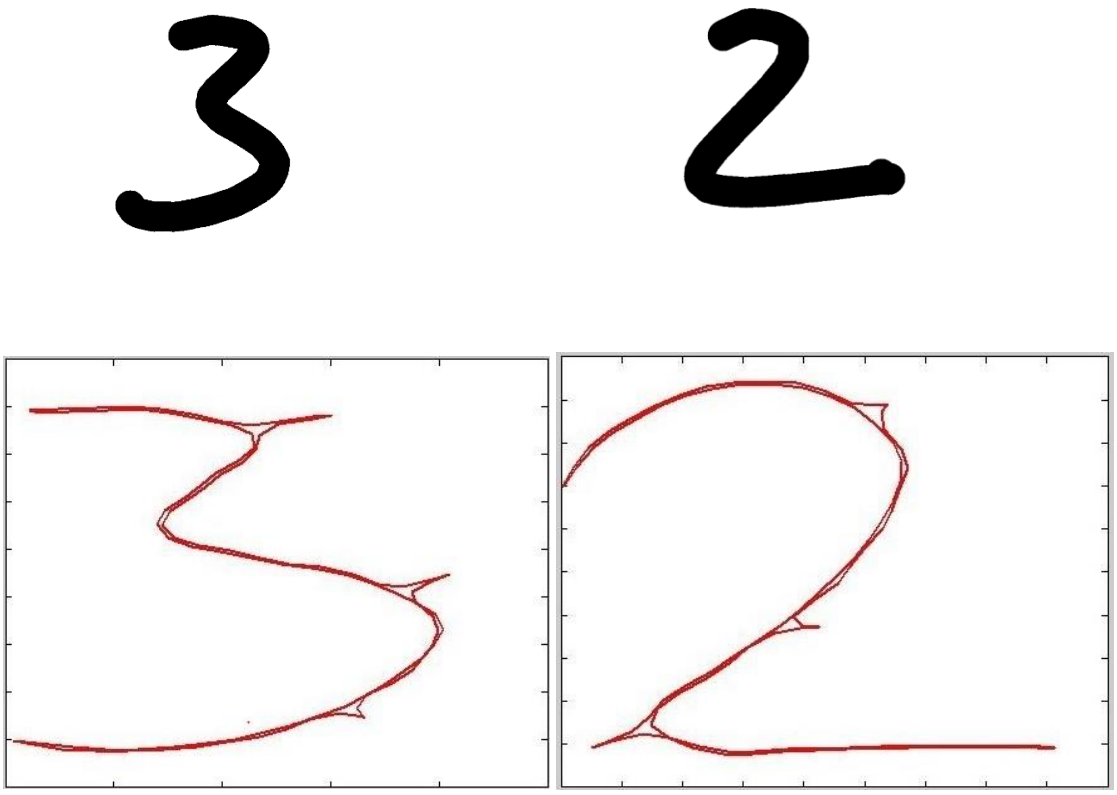


FIG 4.1 FOURIER APPROXIMATION OF THE TWO NUMERIC CHARACTERS 2 AND 3

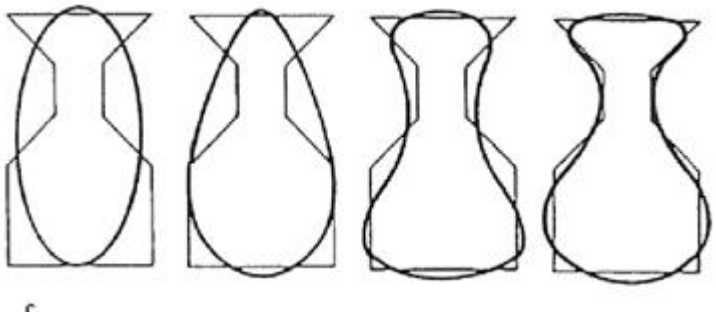


FIG 4.2 1ST, 2ND FUNDAMENATAL, 3RD AND 4TH HARMONICS OF FIGURE 3.2

4.3 NEURAL NETWORK

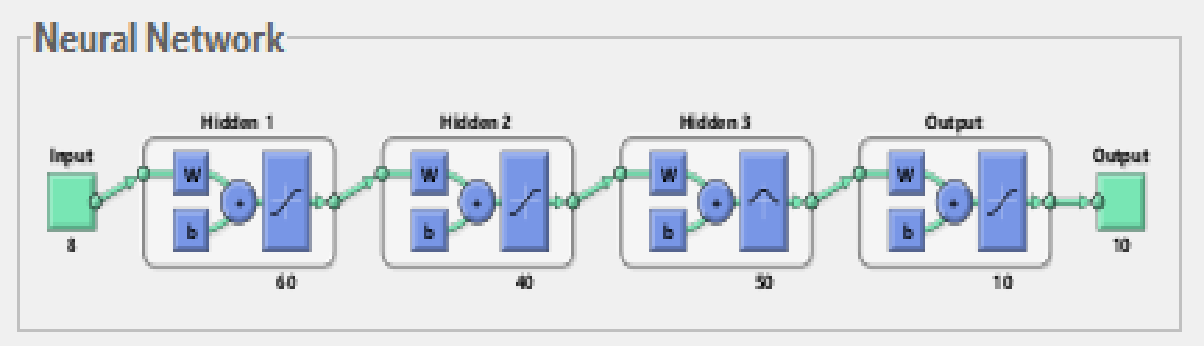
Artificial Neural network are a family of statistical learning algorithms inspired by biological neural networks. The idea behind this is to take features of a large number of handwritten characters known as training samples and from them it develops a system that can learn from those training samples. In other words, it uses the training samples to classify all the inputs. By increasing the number of training samples, the network can learn more about the handwritten character and which finally results in better accuracy.

Neural network basically consists of a number of layers, and these layers are made up of a number of interconnected nodes and every layers has an activation function associated with it. Inputs are given to the network through the input layer and these input layer communicates with the hidden layer where the weight values are set according to which we get output at the output layer.

There are different kinds of learning rules. The one we used here is back propagation technique. In back propagation technique learning is a supervised process which occurs with each epoch through a forward flow of the outputs and then back propagation of the errors for adjusting the weights. We have used different activation function for different hidden layers and we have also defined a minimum gradient.

PARAMETERS OF NEURAL NETWORK:

- No of training samples used: 40
- No of testing samples used: 15
- No of hidden layers: 3
- Transfer function used for layer 1:tansig
- Transfer function used for layer 2:tansig
- Transfer function used for layer 3:radbas
- Transfer function used for layer 4:tansig
- No of epoch: 1500
- Minimum gradient: e^(-7)



NEURAL NETWORK WITH 3 HIDDEN LAYERS AND 1 INPUT AND 1 OUTPUT LAYER

CHAPTER 5

RESULTS AND CONCLUSION

5.1 RESULTS

The program was rigorously tested on 15 sample images, hand written on Microsoft Paint. Since the samples were hand written the experimental results provide a good estimate of the performance of the program.

An analysis of the results have been tabulated as below. Each of the characters were tested for 15 samples.

TYPE OF TRAINING AND RECOGNITION ALGORITHM	ACCURACY OBTAINED
HISTOGRAM OF CHAIN CODES	85.3333%
CO-EFFICIENTS OF FOURIER TRANSFORM OF CHAIN CODE	93.07862%

5.2 CONCLUSION

In this paper, a framework for character recognition of numeral character has been depicted. The recognition and classification precision of the model usage is promising, yet more work needs to be finished. Specifically, no calibrating of the framework has been done as such. Our character division system additionally needs to be enhanced so that it can deal with a bigger mixture of connecting and touching characters, which happens on a regular basis in pictures got from sub-par quality printing material. The character recognition system represented in this paper was based on histogram of chain codes and coefficients of Fourier transform of chain code and it was found that coefficients of Fourier transform of chain code had a better accuracy than histogram of chain codes.

5.3 SCOPE OF IMPROVEMENT

- The efficiency of this character recognition process to incorporate covering and joined characters can be improved by enhancing the character segmentation process. The division of connected written by hand letters can be achieved by new algorithms.

- The present thinning calculation utilized delivers short goads which make reckoning of different properties like pixel densities ,or checking coherence of a picture on occasion broken and corruptive, however dilation or reverse thinning has been done as when obliged ,an enhanced diminishing calculation can be produced to counter the issue of short goads.

- The calculation utilized as a part of this venture however extremely productive in arranging a picture, yet needs pinpoint exactness in distinguishing a particular impeccable match. So as to do as such the calculation needs to rely on upon the distributional properties of the picture, this obliges a thorough study and analysis of specific picture and still thorough programming .This outcomes now and again the limits and restricting conditions being set by hit and trial approach, this can be maintained a strategic distance from by more experimentation and further cautious investigation of complex characters.

CHAPTER 6

REFERENCES

REFERENCES

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